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Design and analysis of Li-Fi system

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***Abstract* - There are research efforts to explore the unconventional communication techniques for the next generation. The overcrowded and limited BW of RF spectrum has paved the pathway for visible light communication. Li-Fi has evolved with the tremendous growing technology. This paper presents a communication system based on Light fidelity (Li-Fi). In this paper, simulation of the transmitter-receiver system has been done. The major contribution of the work is in the signal analysis of transmitted data. We achieved received signal power density for text data type. The variation of received 3D power distribution along with signal to noise ratio at receiver end with respect to perpendicular distance between receiver and transmitter is presented in this work.**

***Index Terms* - VLC, Light fidelity, Li-Fi, Arduino, LED, Photodiode**

1.INTRODUCTION

1.1Visible light communication and Li-Fi

In this modern era there are too many ongoing projects are running in wireless optical communication. The major research aims are to improve the range and bandwidth of data transmission. As of late, wireless innovation has blossomed since wireless transmission is growing in terms of data transfer per day. The fundamental method for communicating information is through utilizing radio waves (electromagnetic). Radio waves have been traditionally used for wireless communication and are effectively realized globally. RF bands are advantageous to acoustic counterparts owing to better propagation speed, BW, throughput, low power requirements. In any case, RF waves can bolster low data transfer capacity (bandwidth) as a result of conservative spectrum accessibility. One of the promising alternative solution for large scale data transmission is domain of Visible Light Communication (VLC). Optical communication has an upper edge by disabling restrictions of RF such as noise minimization and better throughput (Mbps to Gbps range) [1, 2].

Li-Fi (Light Fidelity) is an emergent technique that utilizes the optical spectrum for data transmission. Traditional Wi-Fi (Wireless Fidelity) accounts for handling large area premises, whereas Li-Fi is found aptly faultless for highly compact wireless coverage in confined area and for extenuating RF interference problems. Li-Fi fundamentally emphases on communicating multimedia data using LED-photodiode pair. In this work, the proposed system is mainly based on LiFi technology for communication using light generating source such as LED's. This light fidelity (Li-Fi) communication environment has many advantages over the acoustic communication such as the Li-Fi system is less complex and can provide high data rate transmission, also consumes very low power.

1.2. Li-Fi system with working principle & features

One of the fastest growing research areas in domain of wireless communications is Li-Fi. Figure 1 shows the conventional block diagram with necessary circuit blocks for data transmission. The principle of light sources (primarily LEDs) transmitting the binary data to the corresponding photosensitive receiver is used here.

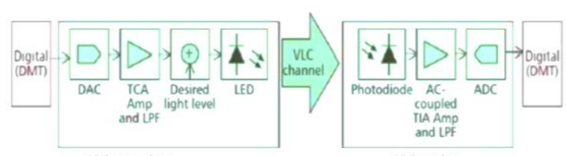


Fig. 1. Elements of visible light communication / Li-Fi system

The basic concept of Li-Fi or data transmission using LED is that binary data 1/0 is communicated corresponding to state of LED being on/Off respectively. The data transfer rate depends on data type. There are various modulation techniques available for Li-Fi communication. We have used simple OOK (On-Off Keying) modulation.

2. LITERATURE REVIEW

S. Srivastava et al. [3] designed a highway navigation system using Li-Fi. The controller at transmitter end provides data routes automated in it. Receiver end used LDR module to absorb transmission rays from transmitter LED's. The received signals via controller are converted back into data.

E. Ifada et al. [4] developed Li-Fi system using common electronic apparatuses. Their embedded arrangement uses ATmega16L connected to input/output components namely LE), LM358N op-amp and a photodiode. They also developed a receiver user interface with JAVA coding to examine the speed, efficiency, security and capacity of the system.

J.K. Xavier et al. [5] proposed a Li-Fi system for data transfer. The input we are using is the ultrasonic sensor. The ultrasonic sensor sends a pulse to the micro-controller if an object is sensed. If there is no object in its range, then the data is not sent. The microcontroller then sends signals to the IC to drive the LED lamp. The LED lamp emits light rays which will be transmitted to the receiver photodiode.

The challenges involved in the hardware implementation for low BW applications involve the choice of suitable controllers, sources, and receiver. The modulation technique used also possess challenge for researchers. The noise and error issues in data transmission is another challenge for large data transmission [6,7]. The design of the proposed system was alienated in hardware and software sections. Arduino is used to interface i.e., encoding, and decoding the data to be transferred using LED blinks at transmitter end and photodiode at receiver end [8-10].

3. HARDWARE IMPLEMENTATION

The transmitter module consists of an input which can consist of an ultrasonic sensor or PIR sensor, micro controller, power supply and an IC to drive the LED lamp. The higher the power of the LED lamp, higher is the efficiency of the IC [10,11]. The receiver side consists of a photodiode which receives the data and sends it to the micro controller for decoding the data [12,13].

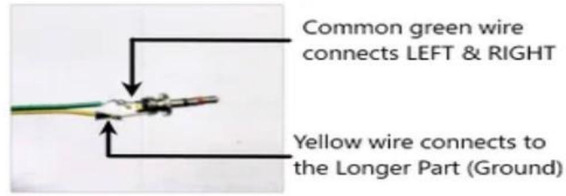


Fig. 2(a). Soldered connections to the jack

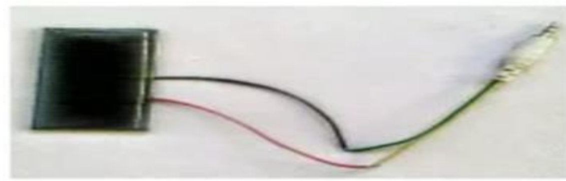


Fig. 2(b). Receiver circuit solar panel

For the hardware tools we used Arduino Uno, white LED and photodiode. For software simulations we have used Proteus, Arduino and Matlab tool.

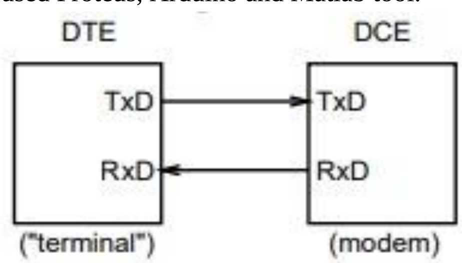


Fig. 3. Block diagram with connections for serial communication

The serial interface with connection between DCE (Data Communications Equipment) and DTE (Data Terminal Equipment). As mentioned in fig. 3, the serial communicating interfacing design has two signals, Transmit Data (TxD or TD) and Receive Data (RxD or RD), along with a reference. TxD is an output for DTE terminal and an input for a DCE terminal. Similarly, RxD is an output from DCE terminal to be input for DTE terminal.

Arduino controller consists of a serial communication interface namely Universal Serial Bus (USB) that is utilized to burn program codes by user. We used IDE platform for our experimental work. The controller was coded to achieve switching LED according to binary encoded data at transmitter end as well analysis of the analog readout from photodiode to digital conversion at receiver end [4]. Also, the use of Arduino eliminates the need of external power supply as it supplies 5 V when connected to system using USB [14,15].

3.1. Software simulations

We carried out simulations using Arduino in proteus environment at baud rate of 1200. Firstly, a single Arduino based serial transmission (refer fig.3) was done for verification of concept.

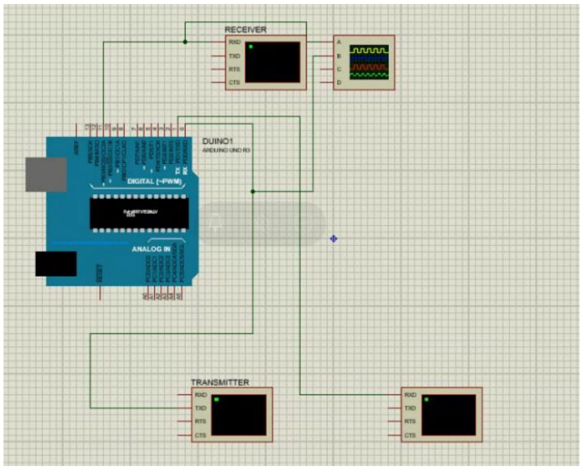


Fig. 4. Circuit diagram with single Arduino for serial transmission

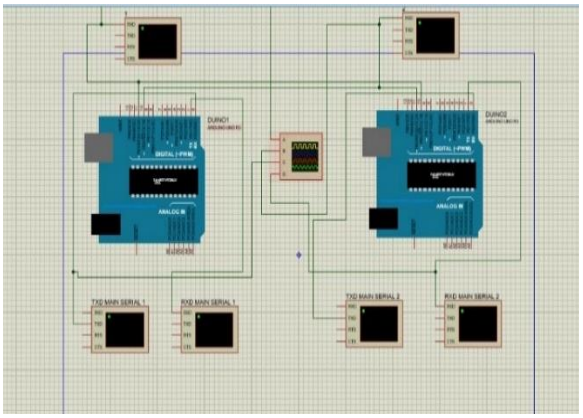


Fig. 5. Simulation circuit design on Proteus Software

We designed a transmitter-receiver system using Arduino microcontroller in the Proteus tool [16]. The design additionally consisted of virtual terminals for data visualization. We also incorporated CRO in our design for real time wave generation. The data transmission was done using serial communication pins of Arduino and corresponding code was loaded in binary format (.bit file). After the design and bit file loading, the software is tested for errors and warning. Before simulations, the cross verification of connections and dumping of microcontroller via loader is ensured. During simulation, the I/O and serial port are initialized, and buffer is cleared. Upon receiving the valid serial transmit signal, the data is transmitted using Li-Fi concept. In the circuit designed for this work, serial receiver (RX digital pin 10) is connected to receiver's TX and for transmitter digital pin 11 is connected to RX of another controller. We connected USB port for serial communication and the data rate setup for serial port real time simulation.

4. RESULTS

4.1. Communication audio signals

Audio signal-based implementation is our previous work using DTMF. In the present work, input signal is provided from 3.5mm audio jack. Received signal is analyzed and final output signal gain is compared with respect to original signal.

Fig. 6. Audio transfer through Li-Fi.

4.2. Communication of text signals

In the Li-Fi communication, the data to be transmitted is priority converted into binary format. The LED blinks accordingly to the binary input data and this complete process is controlled by microcontroller at transmitter side. Similarly, at the receiver end, photodiode or solar panel (any light sensitive device) receives the binary pulses and generates equivalent electrical signals. The microcontroller at receiver side demodulates the signal and generates the output in the original form. We simulated and experimentally performed the Li-Fi communication for both text and audio signals. We monitored the circuits designed for serial communication using OOK modulation technique at baud rate of 1200. We transmitted text from A to Z (26 characters) serially using LED and photodiode at transmitter and receiver side respectively.

The transmitter gets a signal from system utilizing USB port to controller input/output connections. The transistor which works as a switch for voltage supply is regulated by this signal. A Test data sent – a text ("Li-Fi System") encoding involved determining the characters of the text individually in ASCII codes and then converting them to binary bits individually before being transmitted as light signals. Here it tends to be noticed that either of 5 or 12 volts can be used at transmitter for controlling LED yet for straightforwardness and less complexity of the circuits, 5 volts supply is favored for low-power operation. The input light signal is converted to a signal (in electrical form) by the receiver by photodiode and passes to controller. The intermediate op-amp is used for filtering and amplification of the signal. ADC operation is carried out on the signal before giving it to the Arduino because it is in analog form after amplification. Fig. 7 and 8 shows the analog output from the op-amp and controller when either of digital bits is received. The generated current by the photodiode is exceptionally low; hence, it is converted to voltage by a high-value resistor. At last, at the receiver display, the decoded message text is shown using serial transmit window.

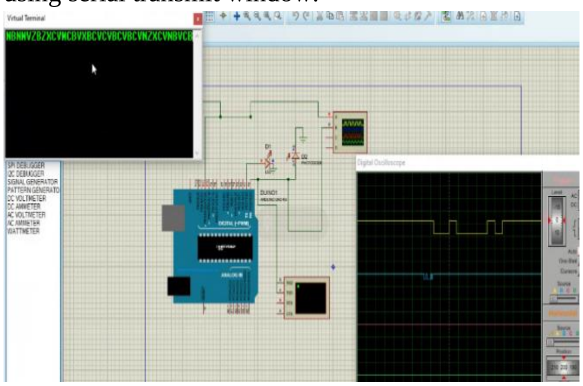


Fig. 7. Result of circuit on proteus software

The CRO attached shows waveforms for each character transmitted at both receiver and transmitting terminals.

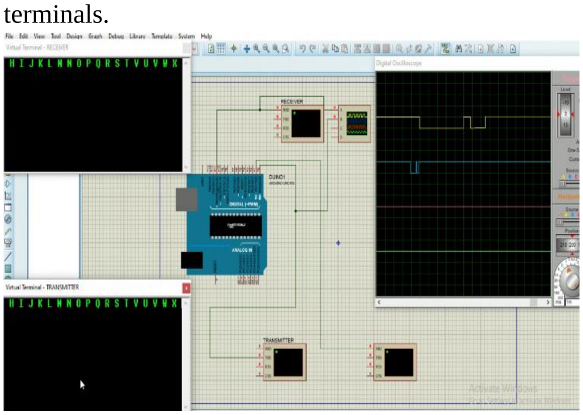


Fig. 8. Result of circuit on proteus software

We verified the concept of data transfer in digital mode and serial communication using LED-Photodiode pair for text in simulations. The speed of communication and accuracy were up to the desired expectations.

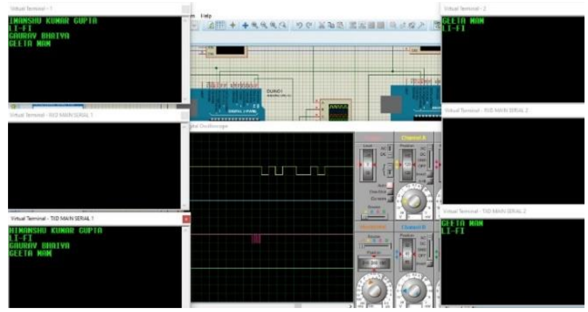


Fig. 9. Result of circuit on proteus software

4.3. Signal analysis

In this sub-section, we show the variation of output signal (fig. 10) parameters focused on power density (fig. 11) and signal to noise ratio.

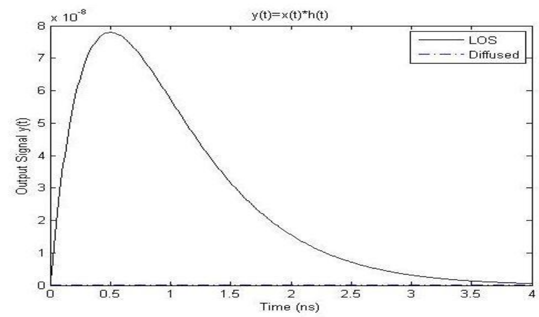


Fig. 10. Variation of output signal with time

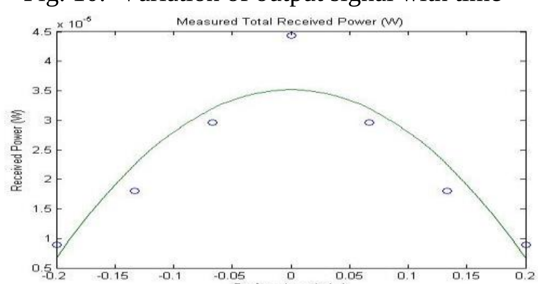


Fig. 11. Variation of received power with respect to distance

The analysis of a Li-Fi system designed is carried out using software-based approach. We have simulated the trans-receiver system using Matlab to obtain the power density and signal to noise ratio at receiver end. The distance between receiver and transmitter plays a crucial role in efficient data transmission as presented in our previous work. Here, we have assumed that transmitter and receiver are placed vertically opposite to each other and the distance between them is termed as height in the curves.

We then simulated the program code to analyze the variation of SNR and received power density of receiver with respect to height. Figures 12 to 17 below shows the three-dimensional characteristic curves for height variation from 0.5m to 5 m. Each figure represents the SNR and power density at receiver end. It is clearly inferred from the graphs that the SNR values and receiver power density curves peak, both get degraded with height or as the distance between receiver and transmitter modules increases.

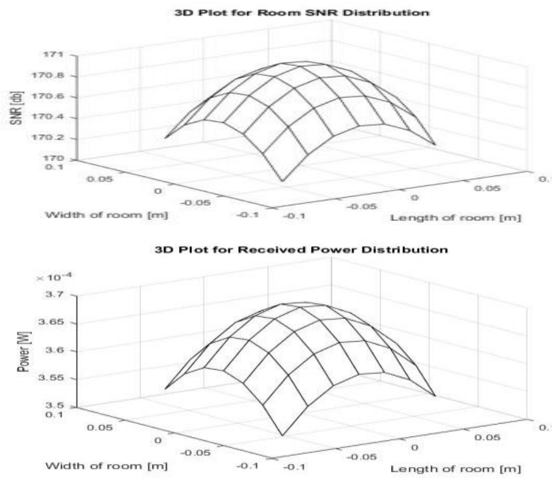


Fig. 12.3D curves for SNR and received power at distance of 0.50 m

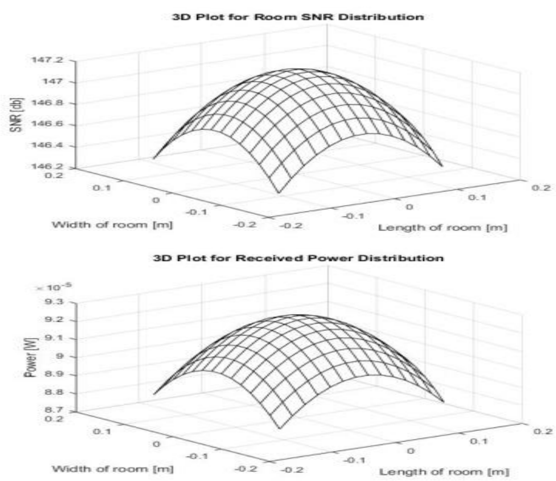
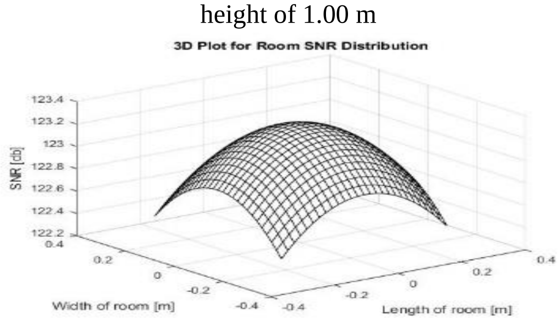


Fig. 13. 3D curves for SNR and received power for height of 1.00 m



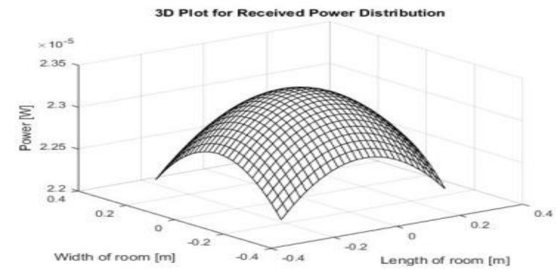


Fig. 14. 3D curves for SNR and received power for height of 2.00 m

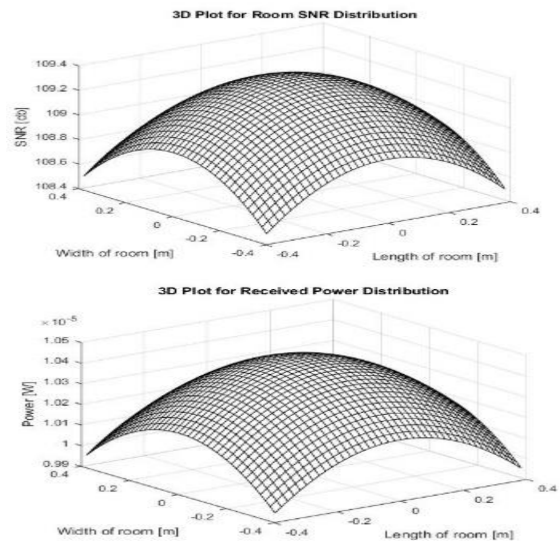


Fig. 15. 3D curves for SNR and received power at distance of 3.00 m

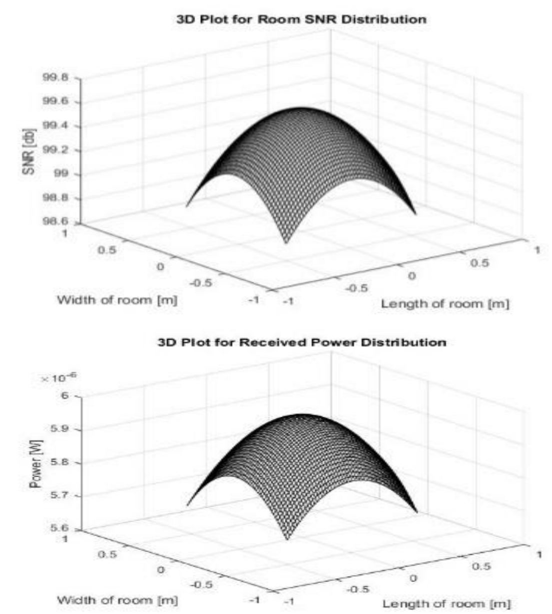


Fig. 16. 3D curves for SNR and received power at distance of 4.00 m

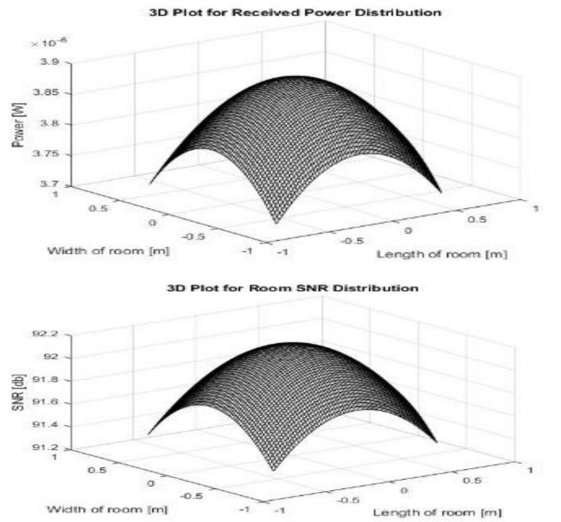


Fig. 17. 3D curves for SNR and received power at distance of 5.00 m

5.CONCLUSION AND DISCUSSION

The purpose of presented work was to project a Li-Fi based data communication arrangement from transmitter to receiver system. The designed system discussed in this work is suitable in parameters such as cost, speed, and data transfer capability.

The arrangement, design, implementation, and simulations of presented work has been performed in research lab. The idea of Li-Fi is of a boundless interest because it offers an efficient substitute against RF wireless communication system. The present work is majorly software based. We are targeting for hardware-based systems capable of communicating with larger data. Achieving more distance of communication and better power efficiency will be targeted for future work. Using the better configuration of devices and arrayed structure the data rates as well as efficiency of data transfer can be improved. From analysis point of view, the angle between the transmitter and receiver followed by optical rays also place a crucial role in the speed and bandwidth of data transmission. We will be targeting to analyze the factor of angle in our future work.

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